GEANT4, NA49, and NA61 Jazz (aka Geant4 Modeling of p+C Interactions and Benchmaking vs NA61 and NA49 data)

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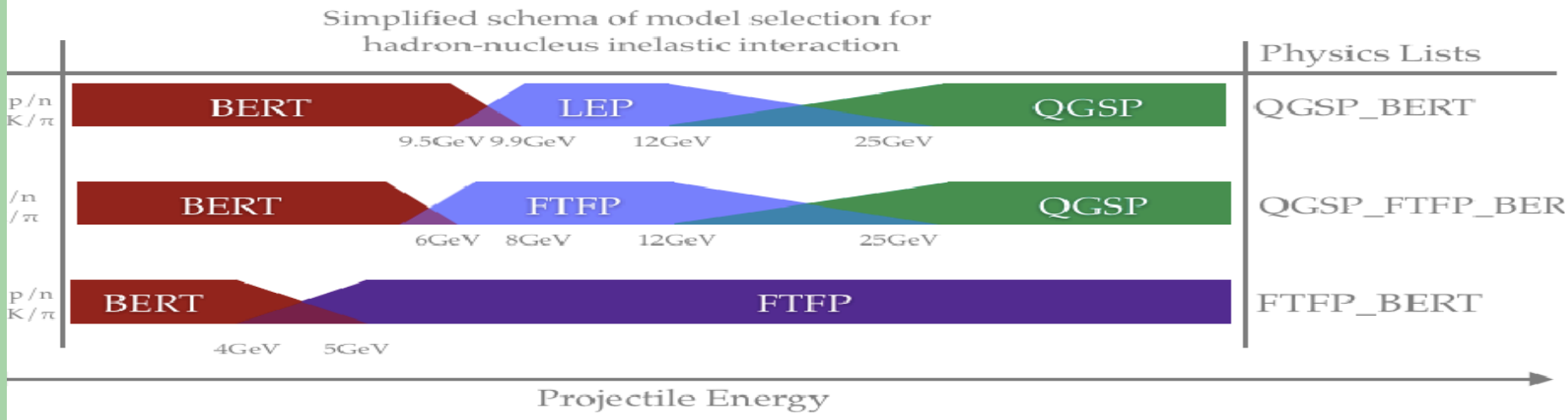
Hadronic Physics in Geant4 - General Remarks

- There is NO "unified" hadronic model
- Hadronic models are valid (or better fit) for combinations
  particle type – energy (- target material)
- Need to choose a set of hadronic models to cover all possible interactions – Physics List (what a user sees)
- The choice is NOT a "black box" but depends on use-case:
  - The particles in simulation
  - The energy scale
  - The compromise between accuracy and CPU
- Collection of ready-to-use physics lists exists
- Users can also tailor any of those, or write their own

Geant4 Physics List Composition - Overlap of Models



NuMI-X: 1st interaction is done by a single model, hence the focus on the HE models in this talk

Further interactions: a mix of everything…

High Energy Hadronic Physics Models in Geant4

- FTF String model: 3GeV – 100TeV
  - Intense development over the past 4-5 years
  - Smooth interface w/Bertini model at intermediate energies
- QGS String model: 15GeV – 100TeV
  - Somewhat "orphan" in the past several year but…
- Each one serves as basis to "HE generator":
  - String model itself (gives name to phys.list)
  - String Fragmentation – G4Lund w/FTF, "old" w/QGS; interchangeable
  - Quasi-elastic channel (internal in FTF, CHIPS-like for QGS)
  - (Typically) Precompound at the back end
- Each one has room for improvement

Experimental Datasets for Benchmarking

- NA61: 31GeV p on C; NA49: 158 GeV/c p on C
  - N.Abgrall et al., Phys.Rev. C84, 034604 (2011) (NA61)
  - Communications with NA61 (proton data)
  - http://spshadrons.web.cern.ch/spshadrons/ (NA49)
- NOTE: Only a portion of datasets incorporated in our G4 tests so far; more will be added shortly
- Additional useful materials:

  talk by L.Zambelli of NA61, at G4/HAD meeting (11/28/12)

https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=218658

includes comparison vs FLUKA

constraints: based on G4.9.5 series

Technical Remarks

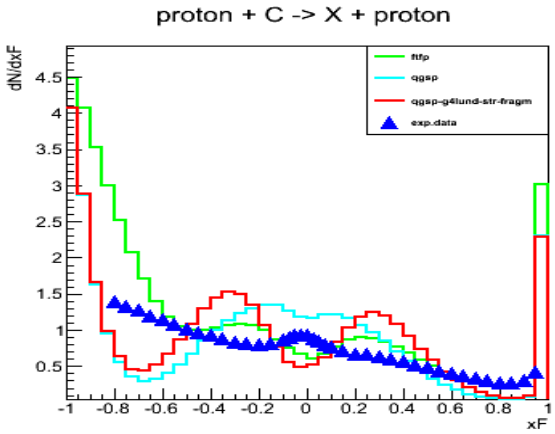
- Results from Geant4.9.6.p01 (should be the same with Geant4.9.6.p02 which is the recommended version)
- Results obtained at the "process level", i.e. from modeling a single interaction
- Same (statistically) as the 1st "ProtonInelastic" interaction (for example, stepping action looks at secondaries at the point where the primary track looses its identity)
- Tests include standard FTFP and QGSP configurations, as in pre-fabricated physics lists…
- … and a custom QGSP+G4LundStringFragmentation combo (not yet available in standard Physics Lists)

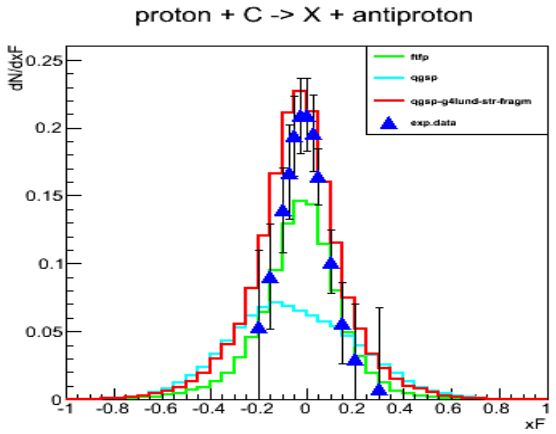
!

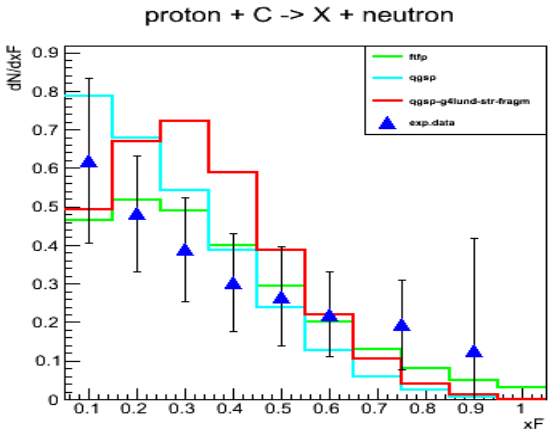
Technical Remarks (cont.)

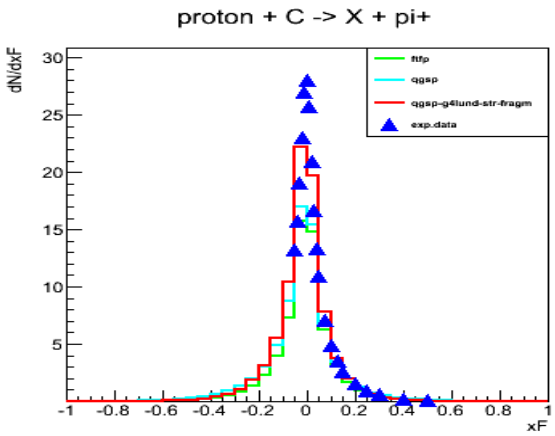
- NOTE-1: quasi-elastic channel is included in the bulk
- NOTE-2 (inspired by Mike K.'s talk on 6/20): our tests may need refinement as it does NOT account for the fact that secondary eta, eta-prime, etc., also decay into pions !

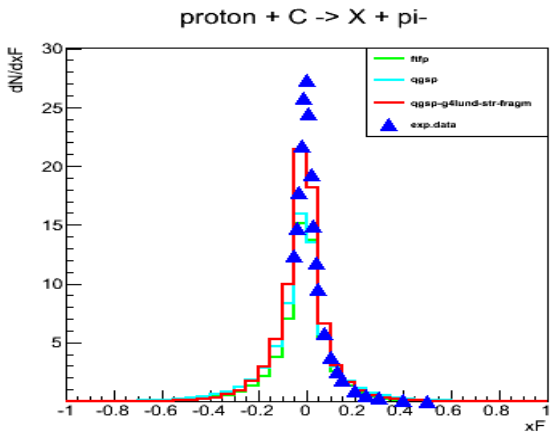
NA49: 158GeV/c proton on C ⟹ p, pbar, n, pi+, pi-





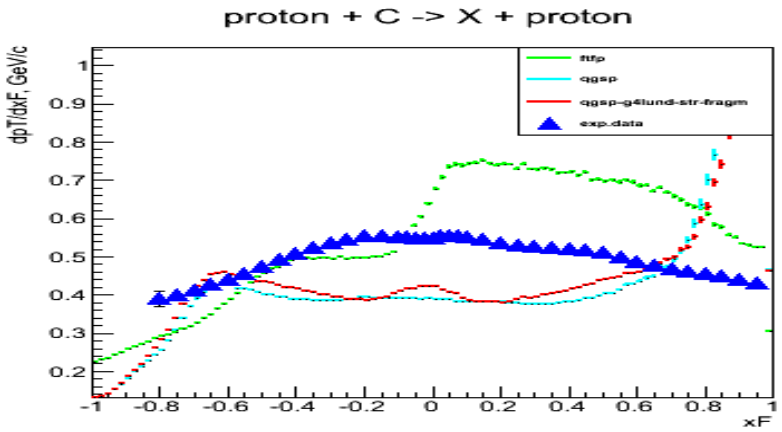


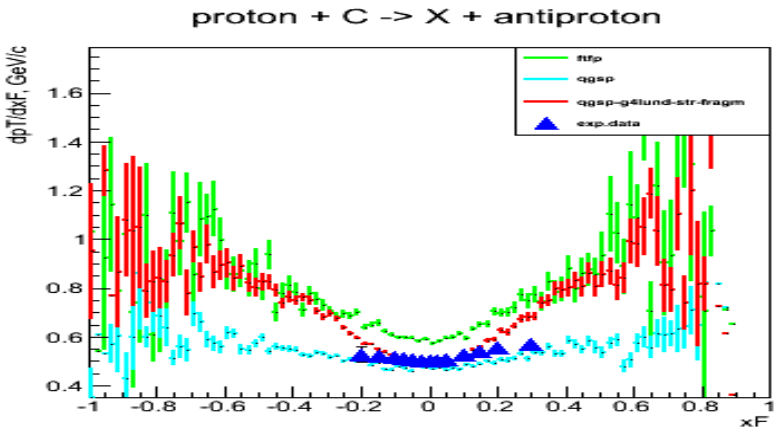


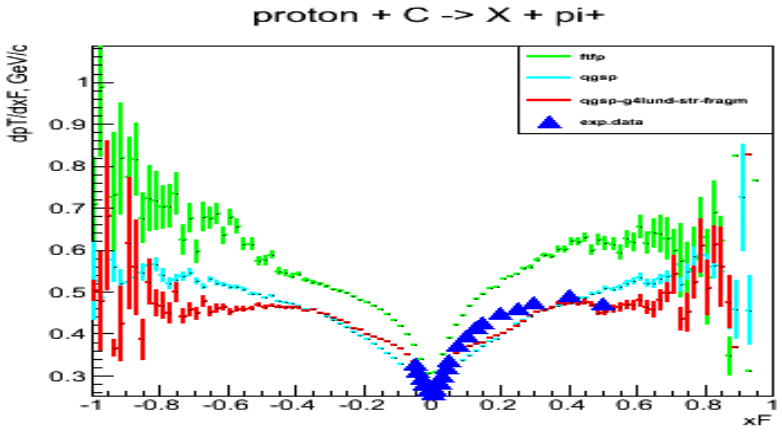


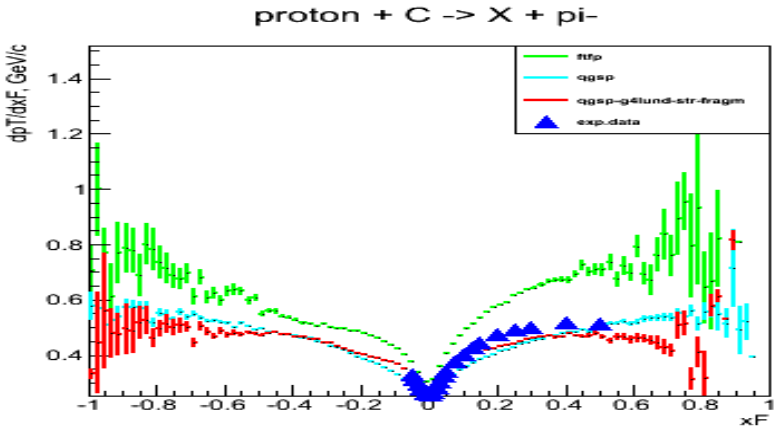
In these plots and onwards:
Green = standard FTFP
Light Blue = standard QGSP
Red = QGSP
+G4LundStringFragmentation

NA49(cont.): 158GeV/c proton on C ⟹ p, pbar, pi+, pi-

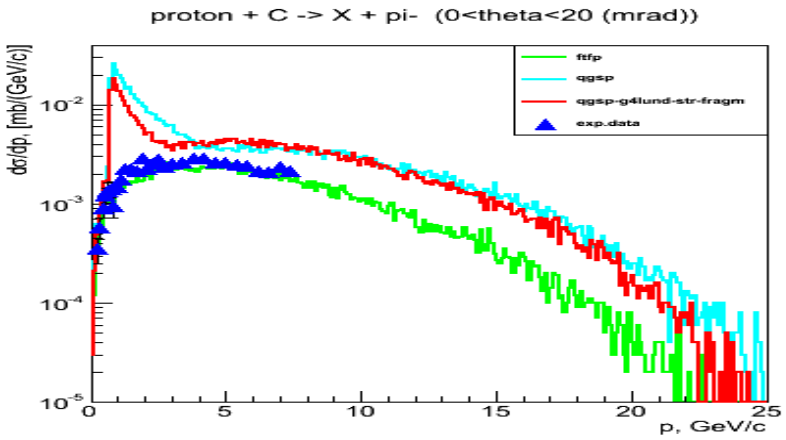


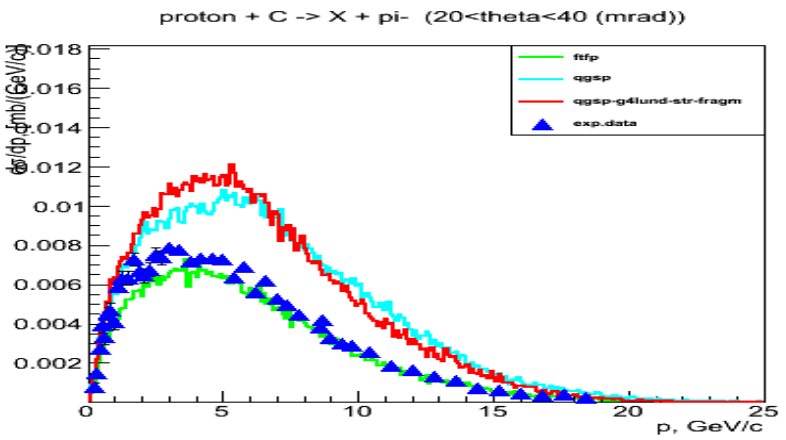


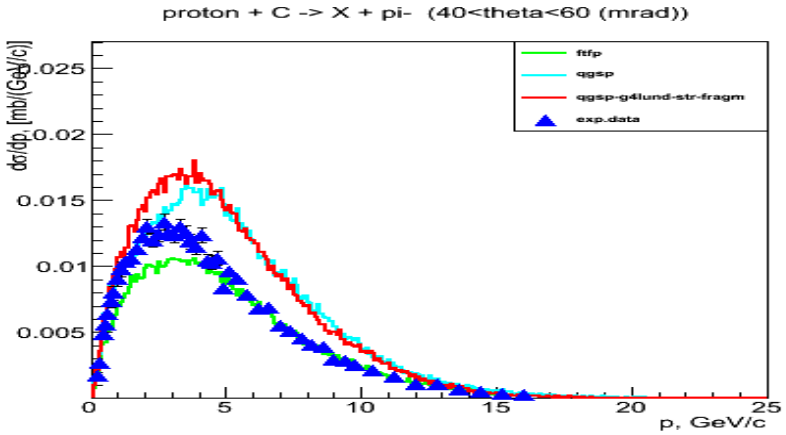


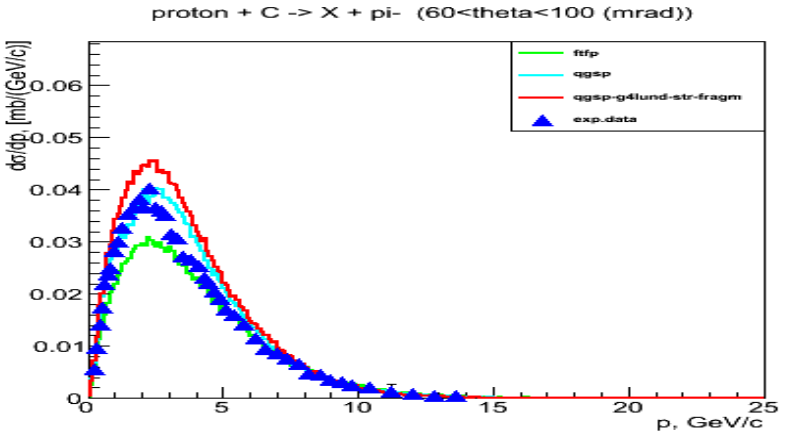


NA61: 31GeV/c proton on C ⟶ pi- + X (theta<100mrad)

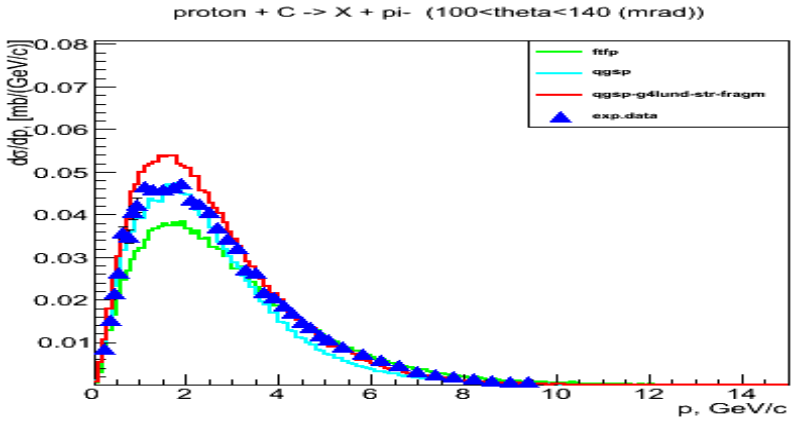


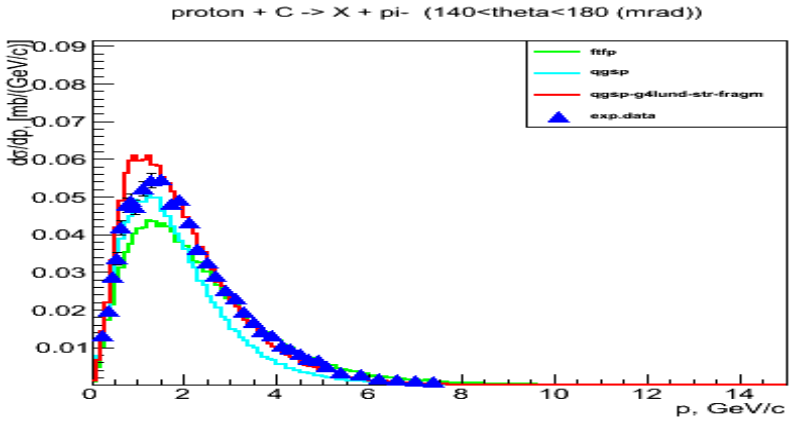


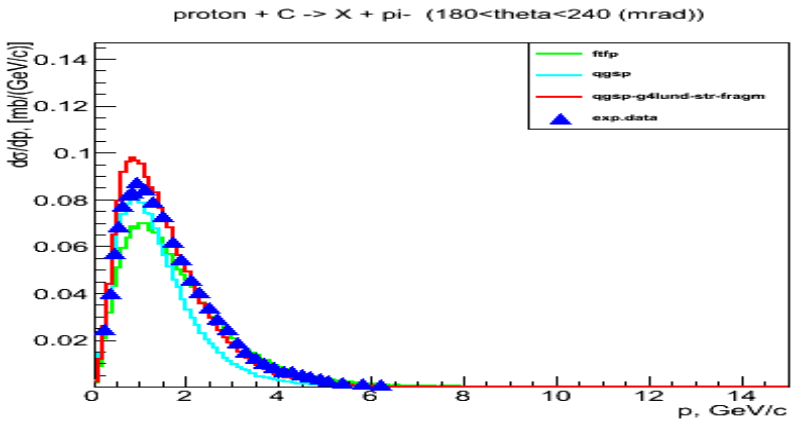


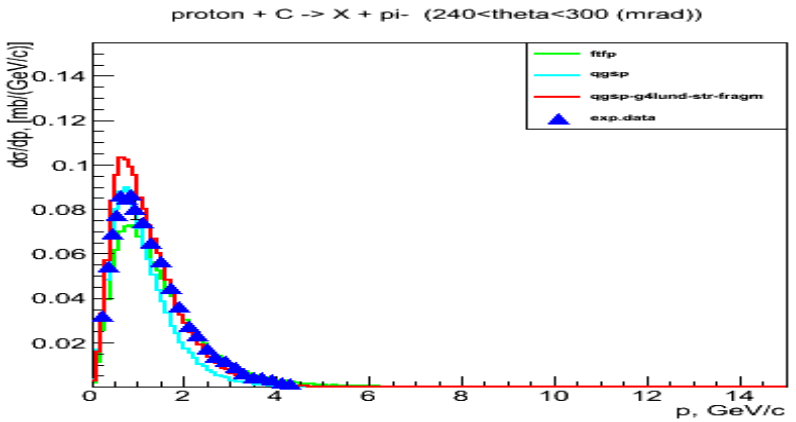


NA61: 31GeV/c proton on C ⟶ pi- + X (100mrad<theta<300mrad)

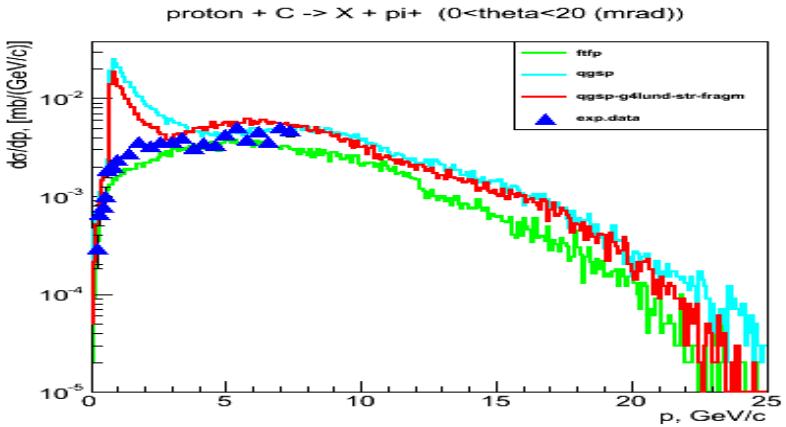


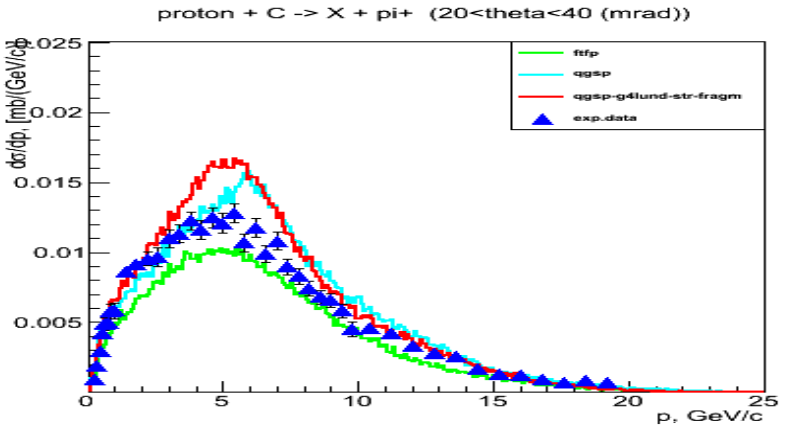


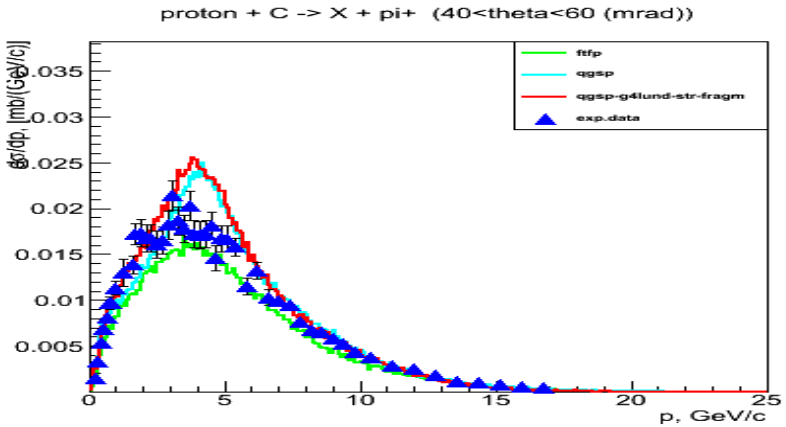


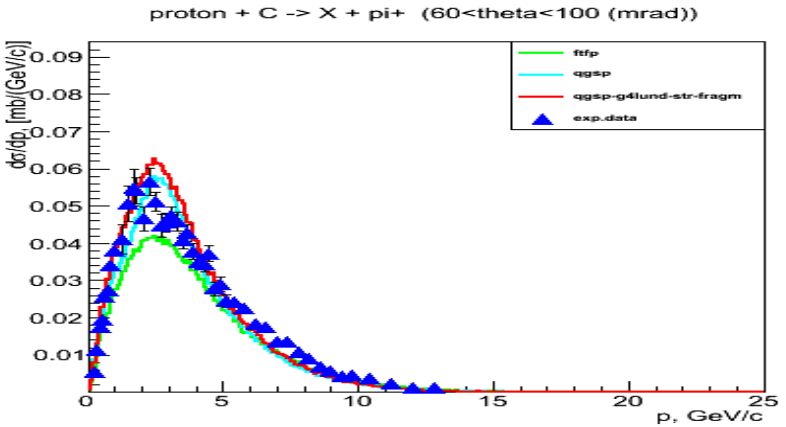


NA61: 31GeV/c proton on C ⟶ pi+ + X (theta<100mrad)

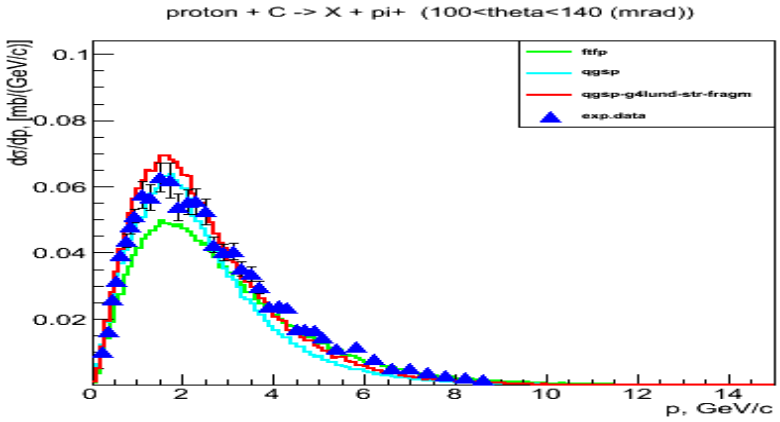


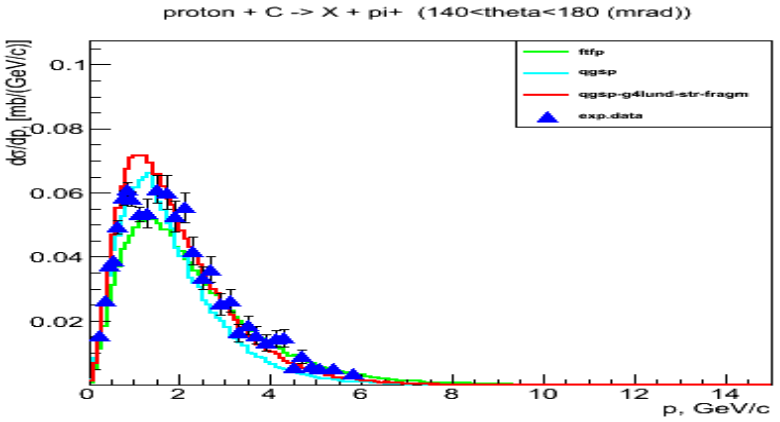


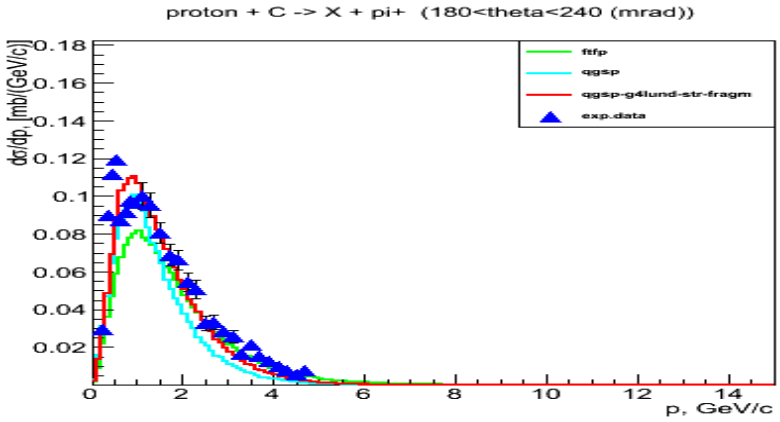


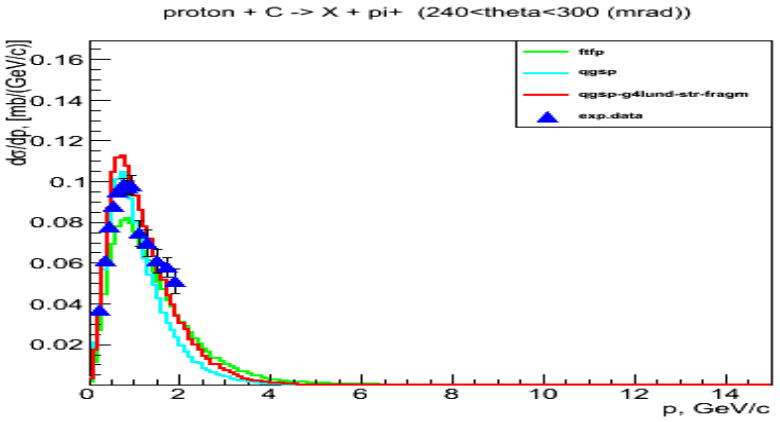


NA61: 31GeV/c proton on C ⟶ pi+ + X (100mrad<theta<300mrad)

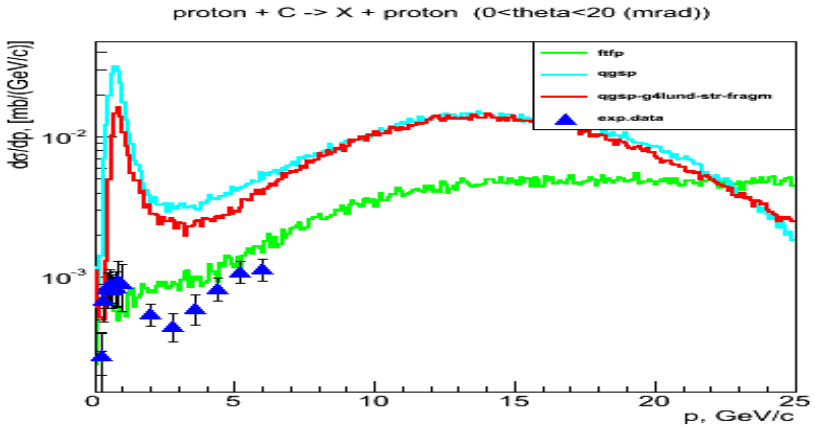


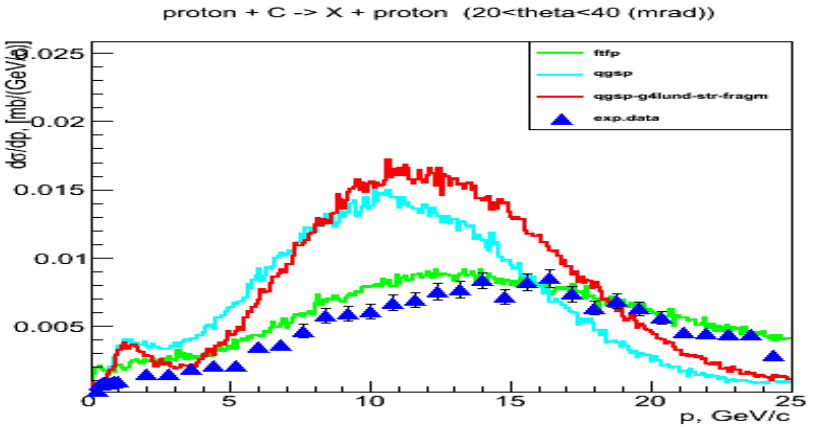


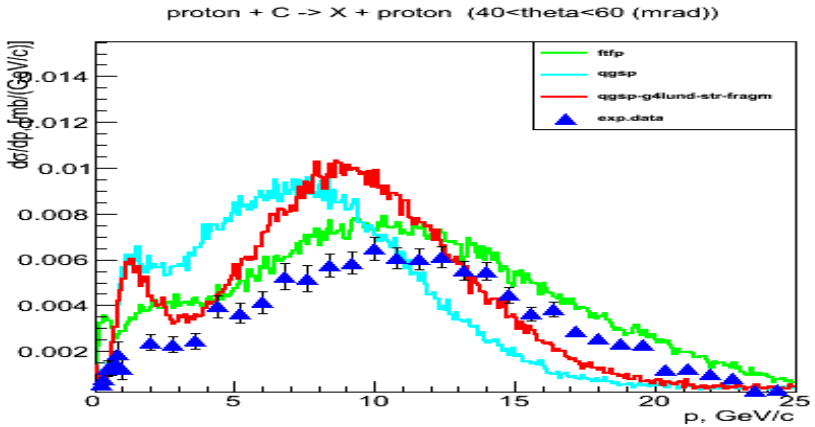


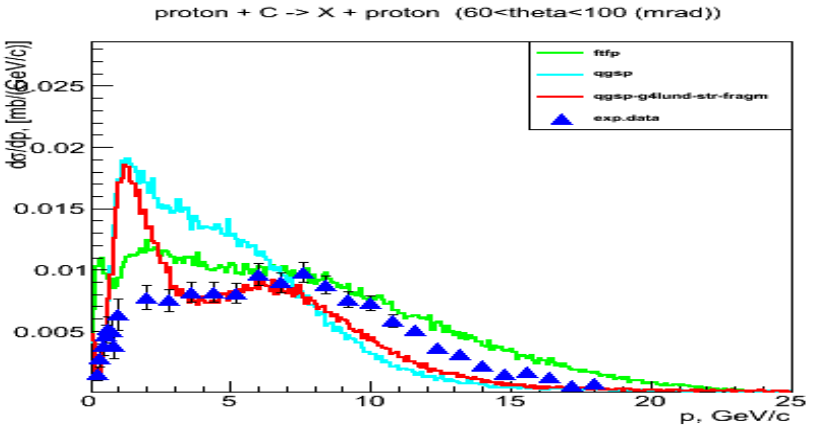


NA61: 31GeV/c proton on C ⟶ p + X (theta<100mrad)

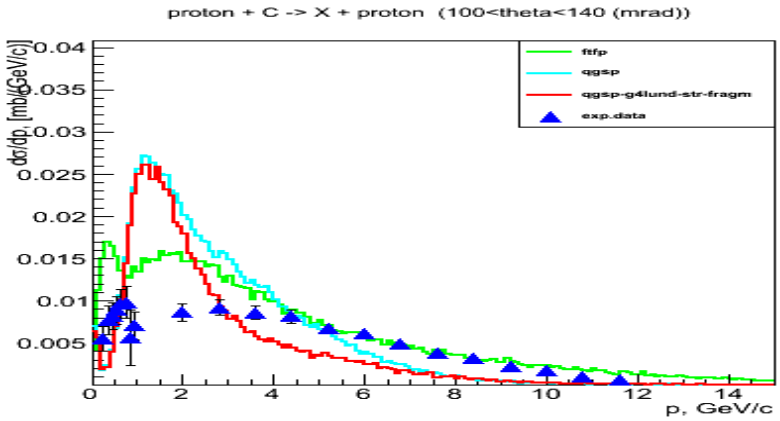


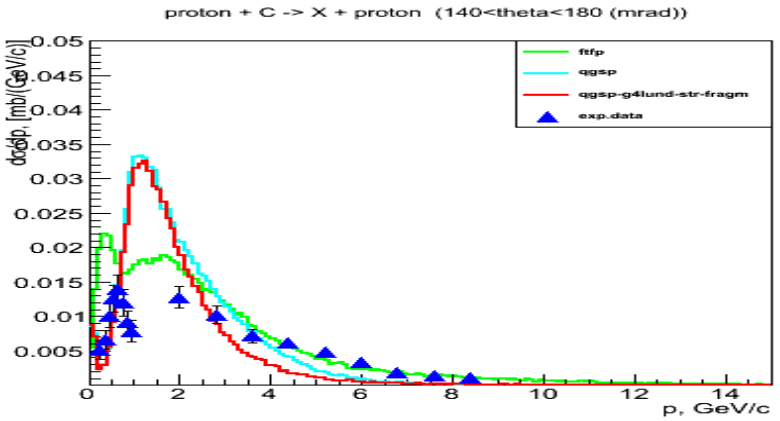


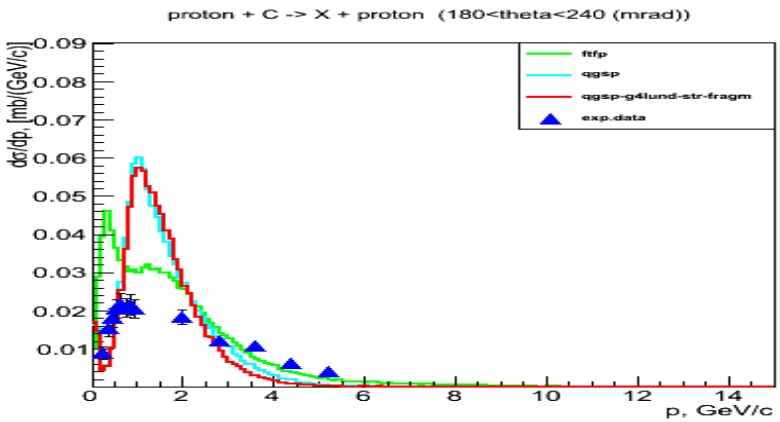




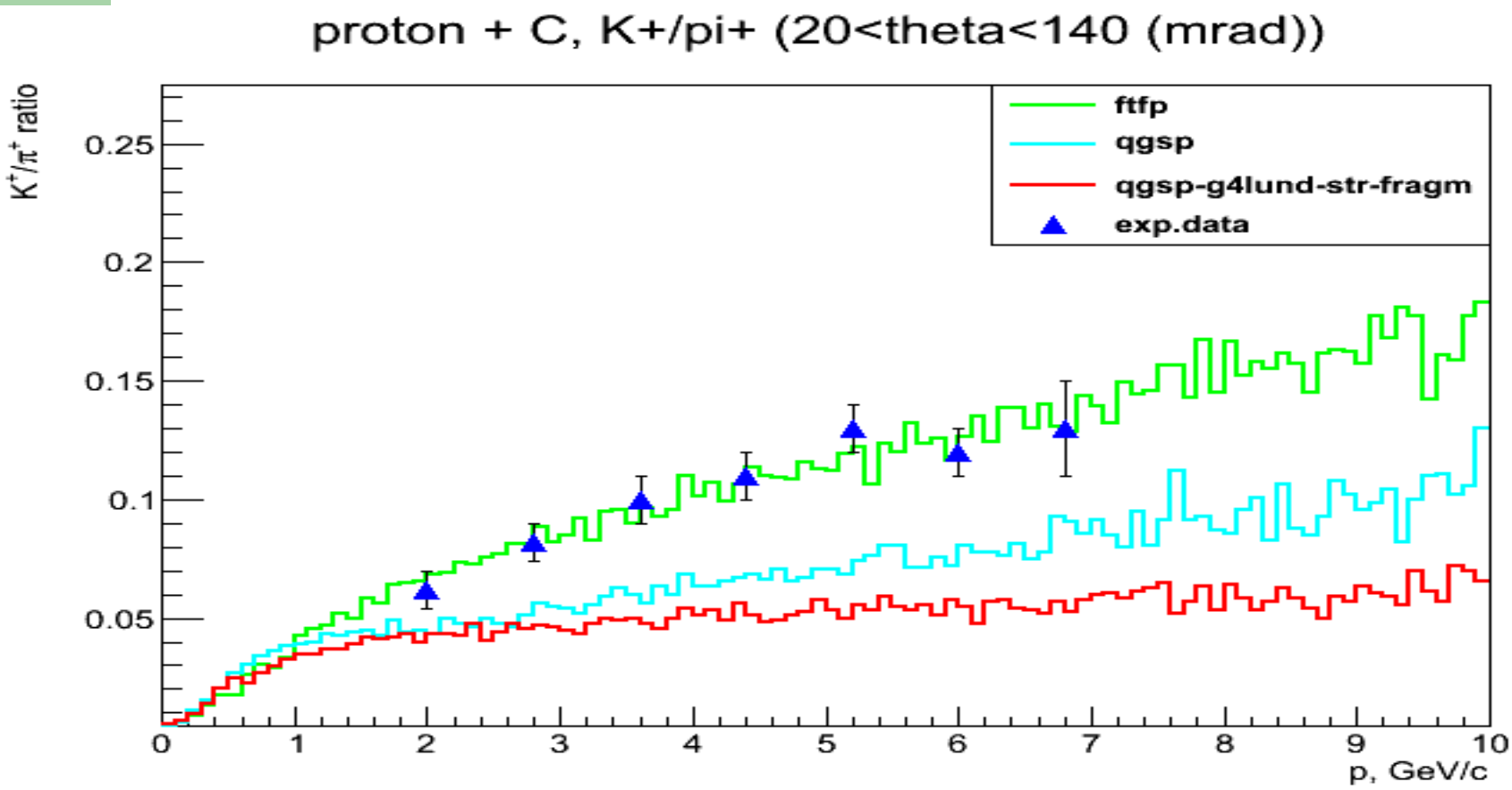
NA61: 31GeV/c proton on C ⟶ p + X (100mrad<theta<300mrad)



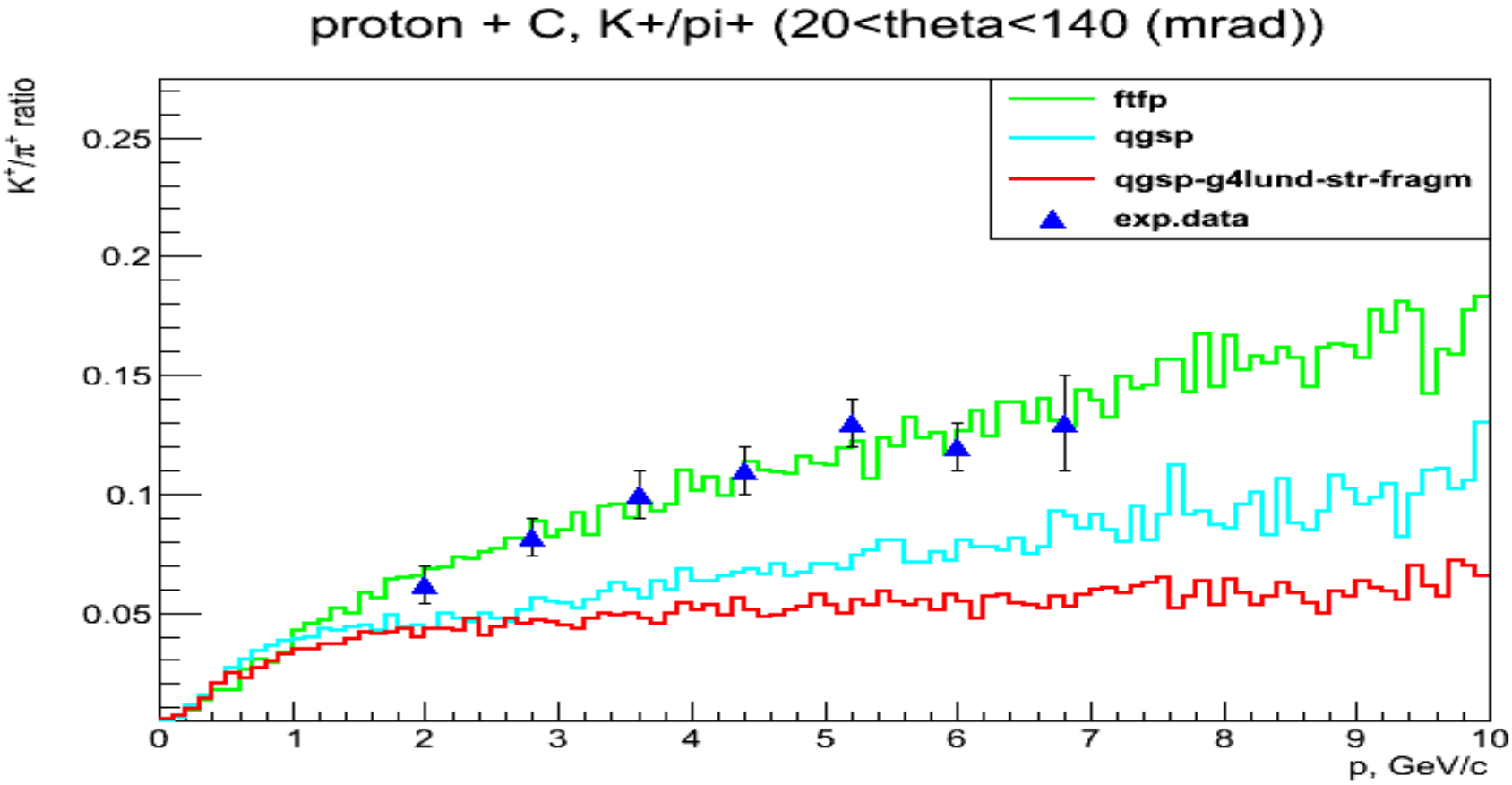




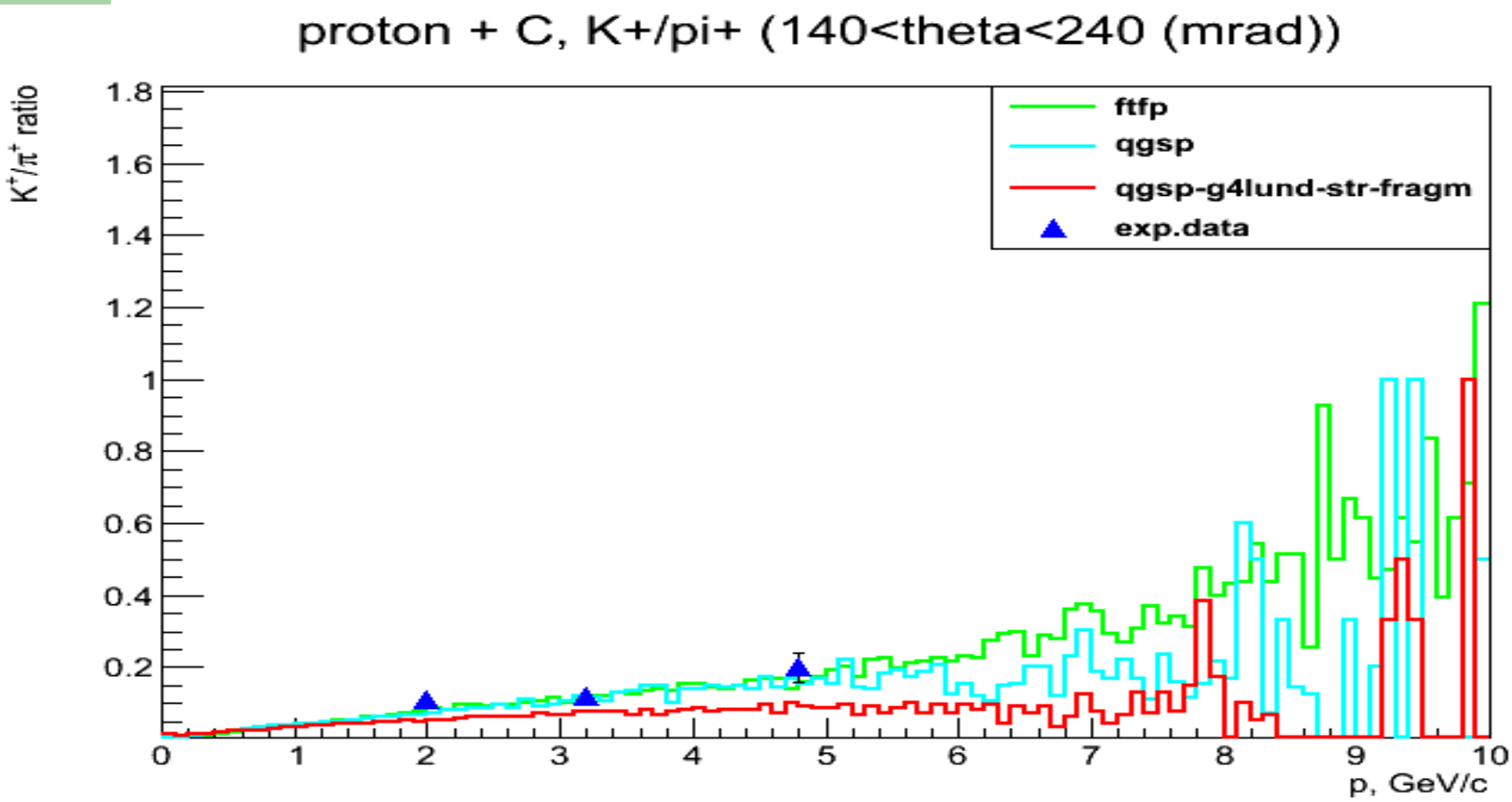
NA61: 31GeV/c proton on C
K+/pi+



NA61: 31GeV/c proton on C
K+/pi+



NA61: 31GeV/c proton on C
K+/pi+ (cont.)



Summary (I)

- Geant4 offers 2 options for modeling HE hadronic interactions: FTF-based or QGS-based
- Each model calls for several other components (quasi-elastic, string fragmentation, intra-nuclear transport…) – some have been worked on recently, some have remained untouched
- Some of these components are "interchangeable"
- Model is per particle type, in a given E-range
- Standard physics lists include particular combination of these, but it can be customized

Summary (II)

- FTF(P) is current and has been worked on recently; in its standard configuration it appears to be reasonable in the several tens GeV range
- QGS(P) is older and remained untouched in the recent past; however, it shows a good fit with the p+C data at higher energies (>100GeV ?), especially with the newer string fragmentation
- Work is in progress
- Feedback is welcome, to trigger improvements

Just FYI: large collection of Geant4 hadronic validation materials is available:

http://g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp